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## AN OBJECTIVE METHOD OF FORECASTING WINTERTIME PRECIPITATION IN NORTHEAST COLORADO

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### ABSTRACT

General aspects of the problem of forecasting precipitation in northeast Colorado are discussed and the forecast area described. A precipitation day for the area is defined on the basis of the number of cooperative weather stations reporting precipitation. Variables with prognostic value in determining upslope flow and, consequently, precipitation in northeast Colorado, are discussed. To obtain a forecasting method, the variables are combined by graphical correlation techniques. The method is tested on independent data; the results are consistent with those obtained on the original data and show a skill score above chance of 50 percent.

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### INTRODUCTION

This study attempts to combine the techniques used in several previous investigations with ideas presented by the forecasters and to apply them to precipitation forecasting for an area. Earlier investigations by Horning [1] and Eberhardt [2] have dealt with forecasting precipitation more for a specific locality than for an area. Others have demonstrated the feasibility of establishing objective methods to be used in precipitation forecasting. This approach does not differ greatly from investigations

made by Vernon [3] in forecasting the occurrence of precipitation at San Francisco or by Penn [4] in forecasting precipitation amounts at Boston. The specific problem of this investigation was the forecasting of precipitation from 12 to 36 hours in advance for northeastern Colorado. The objective was to determine the relationship between data taken from the synoptic charts and the probability of subsequent precipitation. An effort was made to simplify forecast procedures so the forecaster may by a better evaluation of the synoptic situation place a higher degree of confidence in his forecasts.

The data used in the development of the objective procedures were taken from the 1230 GMT (0530 MST) surface weather charts and the 0300 GMT (2000 MST) 700-mb. charts for the months of January, February, and March for the years 1944, 1946, 1947, and 1948. This gives a total of 362 cases which shall be referred to as dependent or original data. Data for the same months of 1945 and 1949 (180 cases) were reserved to test the procedures and shall be referred to as independent or test data. In addition, data for the months of November and December 1947 and 1948 were utilized to test the applicability of the procedures to those months.

### GENERAL ASPECTS OF THE PROBLEM

Several aspects of the problem had to be considered before the development of objective procedures could be

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completed. These include (a) the forecast area, (b) the forecast period, (c) the season of the year, and (d) the definition of a precipitation day for the area.

#### FORECAST AREA

Northeastern Colorado is a natural division of the State from the standpoint of both topography and climate. This area can be described as rolling plains. The elevation rises from approximately 4,000 feet along the eastern boundary to near 6,000 feet at the foothills of the Rocky Mountains. The southern portion of the region is bounded by a ridge of hills known as the Palmer Lake Divide. The elevation of this ridge is about 8,600 feet where it joins the Rockies, but it decreases to near 4,000 feet at the Colorado-Kansas border. Thus, the area is in a rain shadow with storms which produce southerly through northwesterly surface winds over the area. The increase in elevation of the terrain from east to west, however, provides sufficient lift for northerly through southeasterly flow that the resultant cooling may produce precipitation.

#### FORECAST PERIOD

The forecast that is issued in the morning was chosen for the investigation because it holds the place of paramount importance, its issuance coinciding with the users' operational planning. Another reason considered was the time of observations by the cooperative stations used for precipitation verification. For the most part cooperative observers measure the 24-hour amount of precipitation either in the early morning or in the evening. Only the evening observations were used because they lend themselves better to the periods corresponding to the forecasts. To avoid any overlapping of periods the "today" portion of the official forecast was eliminated. Thus the forecast period of this study is the 24 hours from 1730 MST "today" to 1730 MST "tomorrow." This is the same as the "tonight and tomorrow" portion of the official forecast issued from the 1230 GMT charts. No effort has been made to subdivide the period since there is no adequate means of verifying the results. Consequently, it is left to the forecaster to ascertain, if necessary, in which of the 12-hour periods the precipitation will occur.

#### SEASON

The variables used in this study are applicable only to those situations which lead to upslope flow at the surface and subsequent widespread precipitation and are not suited for forecasting thunderstorm activity. The procedures developed are therefore applicable only to the winter season, November to March, inclusive. Although they are based on data for January, February, and March, tests on November and December data indicate that they are equally applicable to those months.

#### DEFINITION OF A PRECIPITATION DAY

The rainfall data from Weather Bureau Cooperative Stations published in the *Monthly Climatological Data*, Colorado Section, served as a basis for determining a pre-

cipitation day. In northeast Colorado there are many Cooperative Stations. No station at an elevation above 6,000 feet was used since precipitation might be unduly influenced by the altitude, and no station that reported or measured precipitation at times not corresponding with the forecast period was used. An analysis was made of the number of times each station reported and only those which reported every month were used. Twenty-one stations were thus selected. The distribution of these stations over the area is shown in figure 1. The definition of a precipitation day was then based on a certain percentage of these stations reporting precipitation. The selection of this percentage is an entirely arbitrary decision. It would seem that the value selected should be as low as possible and still assure a spatial distribution such that at least two quadrants of the area are represented by precipitation reports on a "precipitation" day. From the distribution of the 21 stations used (fig. 1) it can be seen that the greatest number in any quadrant of the area is 7 stations. Thus to assure that at least 2 quadrants are represented, at least 8 of the 21 stations should report precipitation. Further, even though 7 or less stations reporting precipitation were distributed over the entire area (which is usually the case) it would represent a squally condition and not a widespread precipitation situation. A precipitation day for the purposes of this paper, then, is any 24-hour period from 1730 MST one day to 1730 MST the following day during which more than 33½ percent of the stations report precipitation. A trace was considered precipitation.

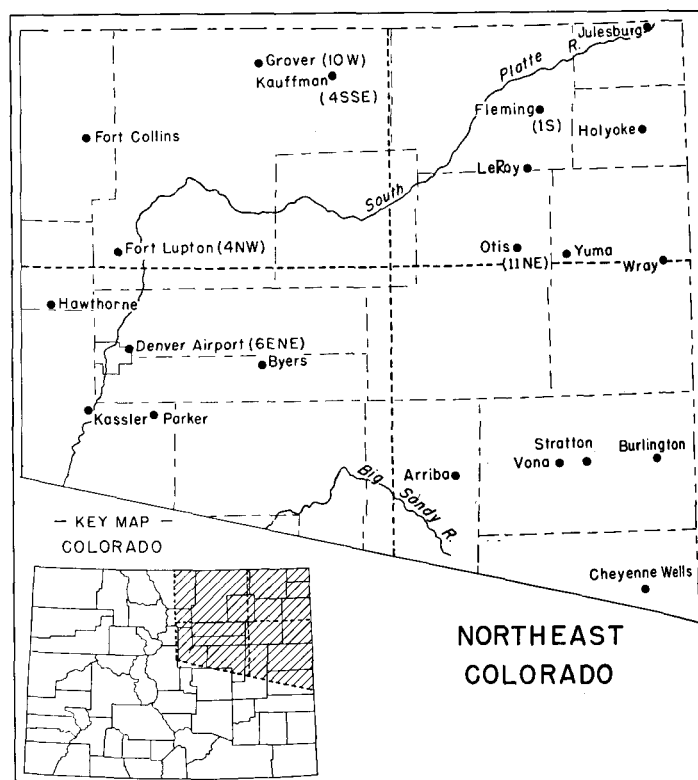


FIGURE 1.—Distribution of Cooperative Stations in northeast Colorado used for verification purposes.

## VARIABLES AND PROCEDURES USED

In selecting variables which might be related to the occurrence of widespread precipitation in northeast Colorado, results of previous research and the experience of the Denver forecast staff formed the main sources of ideas.

The underlying principle in selecting most of the variables was to select those which would either precede the establishing of an upslope situation, or indicate the continuance of an upslope situation, and thus be indirectly related to the occurrence of precipitation. A second consideration was to establish some measure of the moisture available for precipitation formation if upslope conditions developed.

The days were stratified first on the basis of whether or not precipitation was occurring in northeast Colorado at the time of the forecast map (1230 GMT). This stratification was based on the a priori reasoning that variables having prognostic value for the beginning of upslope circulation might be different from those that would indicate the continuance of such a flow once it had begun. Also, if precipitation was already occurring, no moisture variable would be necessary since precipitation once started would be expected to continue until upslope flow ceased. Since cooperative stations do not report their observations daily, six stations of the synoptic network in and near the area were chosen for determining the occurrence of current precipitation in the region. These stations are Cheyenne, Wyo., Sidney and North Platte, Nebr., Denver and Akron, Colo., and Goodland, Kans. The definition of current precipitation for the purposes of this stratification is precipitation in any form occurring at any one of these six stations at the time of the 1230 GMT synoptic report. If precipitation is occurring the day is classified as a "P" case. It should not be confused with the precipitation day used in the verification. If no precipitation is occurring at any of the six stations the day is designated as an "NP" case.

## NP CASES

The following discussion of variables and procedures applies only to "NP" cases as defined above.

One of the simplest, but very effective, variables found to indicate whether or not northeastern Colorado will have upslope or downslope conditions during the forecast period is the 1230 GMT sea level pressure at Salt Lake City. This pressure in effect indicates the presence or absence of a plateau High as well as the strength of the High if one is present. Horning [1] found a strong relationship between this variable and the occurrence of precipitation at Denver. Figure 2 shows the relationship between the sea-level pressure at Salt Lake City and the frequency of occurrence of precipitation in northeast Colorado, verified on the basis of the percent of Cooperative Stations reporting, as outlined above. The dots connected by dashed lines represent the frequency of occurrence in class intervals of 2 mb. The crosses connected by thin solid lines are values of frequency of

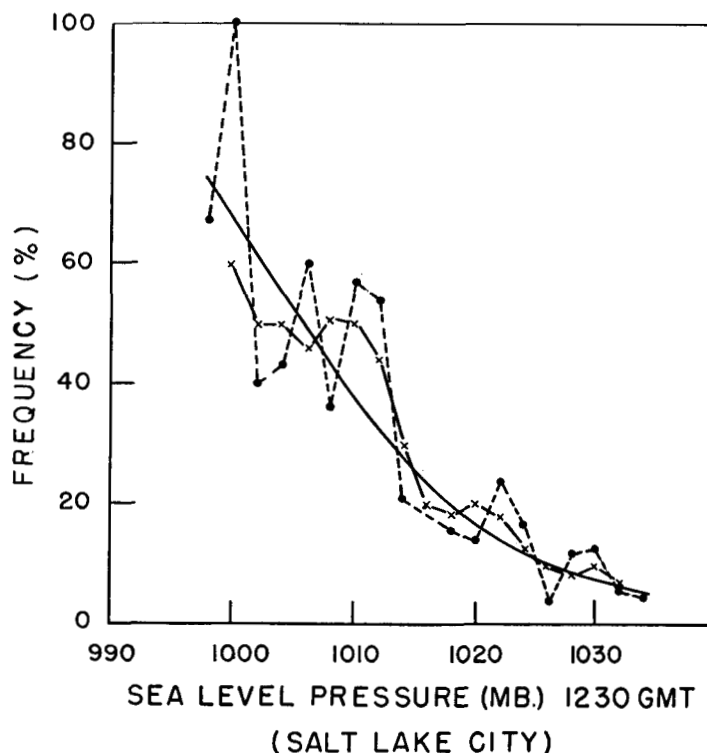


FIGURE 2.—Relationship between Salt Lake City sea level pressure and frequency of occurrence of precipitation in northeast Colorado during the forecast period. Dots connected by dashed lines represent the frequency in class intervals of 2 millibars. Crosses connected by solid lines are smoothed values by consecutive overlapping 3-class intervals. The smooth solid line is a freehand curve fitted to the crosses. (For NP cases)

occurrence smoothed by consecutive overlapping of 3-class intervals. The heavy solid curved line is a freehand curve fitted to the crosses.

Another simple, but effective, variable which gives an indication of the availability of sufficient moisture to produce precipitation in northeast Colorado is the presence or absence of precipitation in eastern Montana. This two-category variable was measured by noting the current and past 6-hour precipitation recorded on the 1230 GMT surface chart at the following six stations in or near eastern Montana: Havre, Billings, Lewistown, Miles City, and Glasgow, Mont., and Sheridan, Wyo. If current or past precipitation (including traces) was reported at any one of these stations, the variable was classified as "precipitation in eastern Montana"; otherwise, as "no precipitation in eastern Montana." Table 1 shows the relationship between this variable and subsequent precipitation in northeast Colorado, indicating

TABLE 1.—Relationship of precipitation and no precipitation in eastern Montana to subsequent precipitation in northeast Colorado (For NP cases)

	Total number of cases	Subsequent precipitation in northeast Colorado	
		Number of cases	Percent
No precipitation in eastern Montana.....	155	16	10
Precipitation in eastern Montana.....	109	48	44

a much higher frequency of occurrence when the variable was in the category "precipitation in eastern Montana."

The combination of the two above variables leads to a stratification such that if there is no precipitation in eastern Montana and the Salt Lake City sea level pressure is greater than 1,016 mb., the probability of precipitation occurring in northeast Colorado during the forecast period is only 3 percent. When this combination of circumstances exists, a no-precipitation forecast should be made for northeast Colorado. These results are summarized in table 2. The critical value of 1,016 mb. was arrived at by an expanded plot of the two variables. The cases falling in the quadrant labeled "B" in table 2 will be referred to as NP-B cases and those in the other three quadrants as NP-A cases.

TABLE 2.—Joint relationship of the Salt Lake City sea level pressure and the eastern Montana precipitation variable to subsequent precipitation in northeast Colorado. The numerator of the fraction in each joint category gives the number of cases of subsequent precipitation in northeast Colorado; the denominator, the total number of cases (For NP cases)

	Precipitation in eastern Montana	No precipitation in eastern Montana
Salt Lake City sea level pressure $\leq 1016$ mb. ....	$\frac{29}{59}$ 47% A	$\frac{13}{41}$ 42% A
Salt Lake City sea level pressure $> 1016$ mb. ....	$\frac{20}{50}$ 40% A	$\frac{3}{114}$ 3% B

Two other variables taken from past research were applied to the NP-A cases. Horning [1] developed a sea level pressure index (hereinafter referred to as the surface index) which gives an indication of whether or not upslope flow will prevail along the east slope of the mountains during the forecast period. This index is the difference between the summation of sea level pressures along the 40th parallel at points 105°, 110°, and 115° west longitude (points D, E, F in fig. 3) and the summation of pressures along the 50th parallel at the same longitudinal intersections (points A, B, C in fig. 3). The northern summation is subtracted from the southern with positive values indicating westerly or downslope flow and negative values easterly or upslope flow.

In an independent study Eberhardt [2] developed a 700-mb. index related to precipitation at Denver. If an upper-air trough of sufficient strength crosses the coast in the area of northwestern United States or British Columbia, it will continue eastward over the Rocky Mountains and will be a factor contributing to precipitation in northeast Colorado. One measure of the strength of such a trough can be obtained from a meridional index computed from the contours of the 0300 GMT 700-mb. chart. This index is computed by subtracting the sum of the 700-mb. heights at the points labeled A, B, C, and D in figure 4 from the sum of the heights at the points E, F, G, and H. A positive value of this index indicates southerly flow; a negative value, northerly flow.

These two indices of surface and upper air flow were related graphically to the occurrence of precipitation in northeast Colorado in a scatter diagram as shown in figure 5. Only NP-A cases are plotted on this chart. At the point determined by a pair of values of the indices the occurrence of subsequent precipitation was indicated by a cross, or non-occurrence, by a dot. All values of the 700-mb. index outside the range of the scale given in figure 5 were plotted on the 100 line, positive or negative as appropriate. The chart was then divided into three areas based

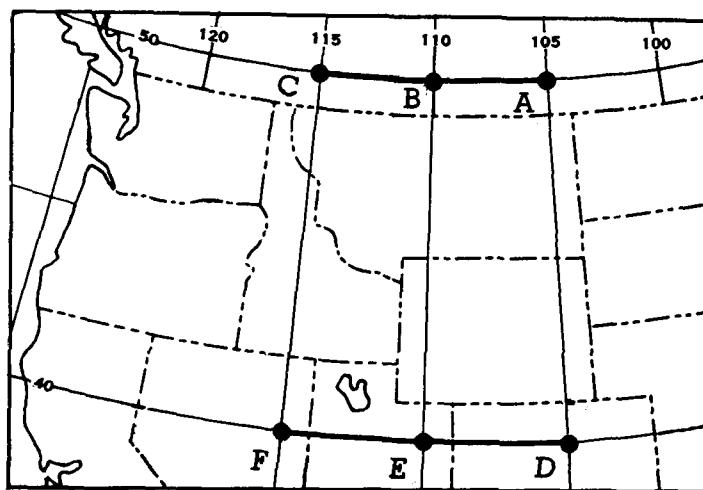


FIGURE 3.—Points used in computing surface index. Obtain 1230 GMT sea level pressure (mb.) at each point; surface index =  $(D + E + F) - (A + B + C)$ .

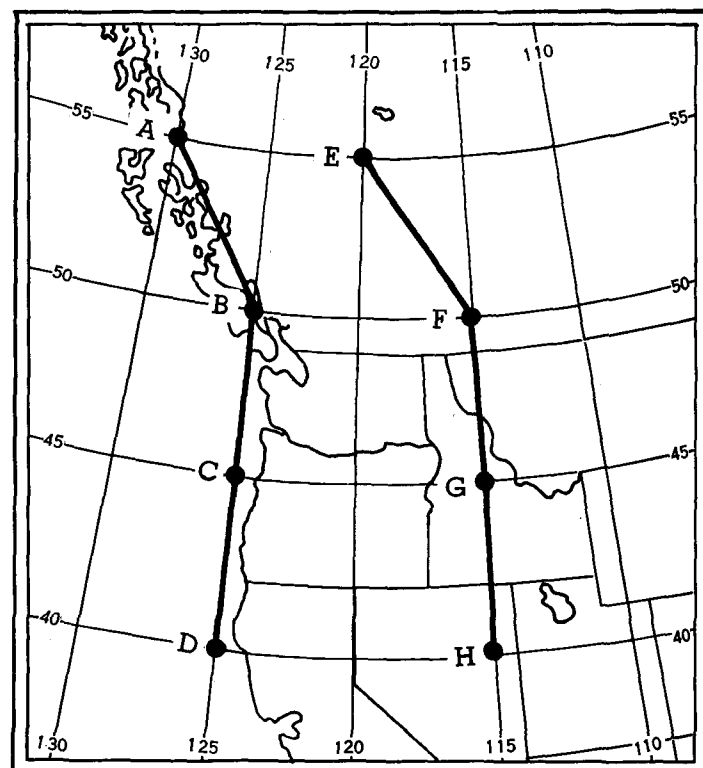


FIGURE 4.—Points used in computing 700-mb. index. Obtain 0300 GMT 700-mb. height at each point; 700-mb. index =  $(E + F + G + H) - (A + B + C + D)$ .

on the percentage frequency of occurrence of precipitation as indicated. Each area was given a category number with the area of lowest percentage labeled Category I.

Extensive use is made of the 12-hour sea level pressure change chart at the Denver Forecast Center. An attempt was therefore made to incorporate the information contained in this chart (0030 GMT to 1230 GMT) into the objective procedures. It is emphasized that the one simple objective measure finally adopted from this chart by no means extracts all the information. In the authors' opinion an experienced forecaster uses the relative size, shape, intensity, and movements of the centers of rises and falls, which are extremely difficult to measure or express objectively.

The position and intensities of the centers of rises and falls were investigated in relation to the occurrence of precipitation in northeast Colorado; the position of the center of falls seemed to be most closely related. Neither the position of the center of rises nor the intensities of the centers improves materially the results obtained from the position of the center of falls alone. The position of the center of greatest falls within the area bounded by the 95th and 125th meridians and the 30th and 55th parallels

of latitude was obtained. If no *center* of falls lay within the area, the position of the greatest fall within the area was taken. This distinction is important, for it is quite possible to have a separate center of falls within the area which is not necessarily the greatest fall in the area, since a large fall might exist at the edge of the area reflecting a large-fall center outside the area.

At the position thus obtained the occurrence or non-occurrence of precipitation was plotted on a base map of the area, a cross again representing precipitation, and a dot, no precipitation. As shown in figure 6, the area was divided into five separate zones according to the frequency of occurrence of precipitation. Again, only NP-A cases were plotted on this chart.

The variables for NP-A cases were combined by a slightly modified form of the graphical correlation techniques used by Brier [5] and others [6 and 7]. Categories from figures 5 and 6 were used as coordinates of a third chart, figure 7. For each day category numbers were determined from figures 5 and 6 and the total number of cases in each combination of category numbers was tabulated. The number of precipitation occurrences was also noted. These numbers, entered in figure 7 as a fraction at the point determined by each pair of category numbers, give the frequency of occurrence of precipitation at each point. Lines were again drawn separating the data according to the frequency of occurrence. For forecasting purposes the solid line in figure 7 is the best line of separation. A forecast of precipitation is made above the line and no precipitation below the line.

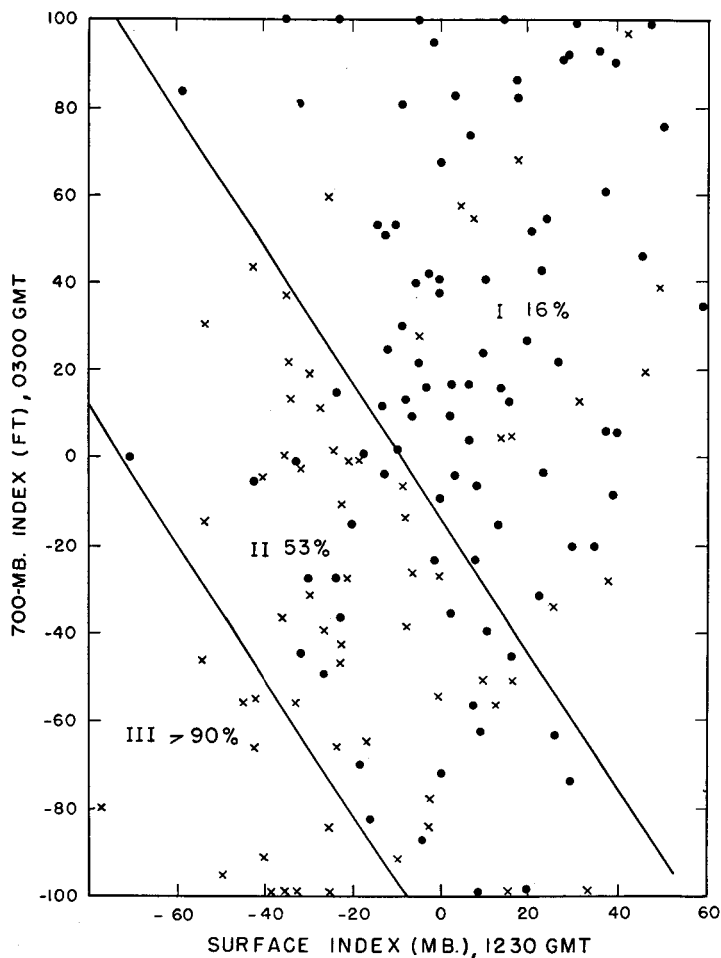


FIGURE 5.—Scatter diagram showing the joint relationship of the surface index and the 700-mb. height index with subsequent precipitation in northeast Colorado. A cross indicates precipitation and a dot no precipitation. (For NP-A cases)

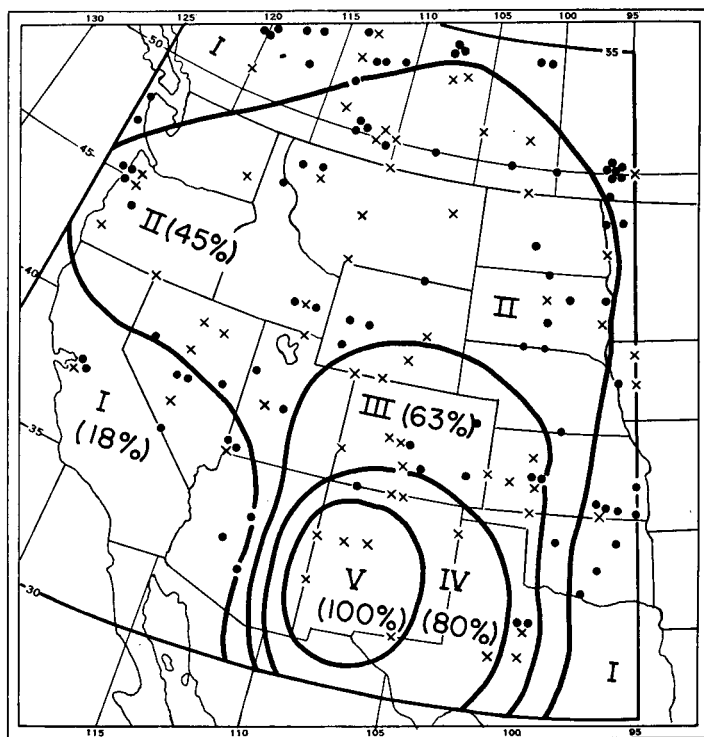


FIGURE 6.—Relationship between the position of center of 12-hour pressure falls in the area indicated and subsequent precipitation in northeast Colorado. A cross indicates precipitation and a dot no precipitation. (For NP-A cases)

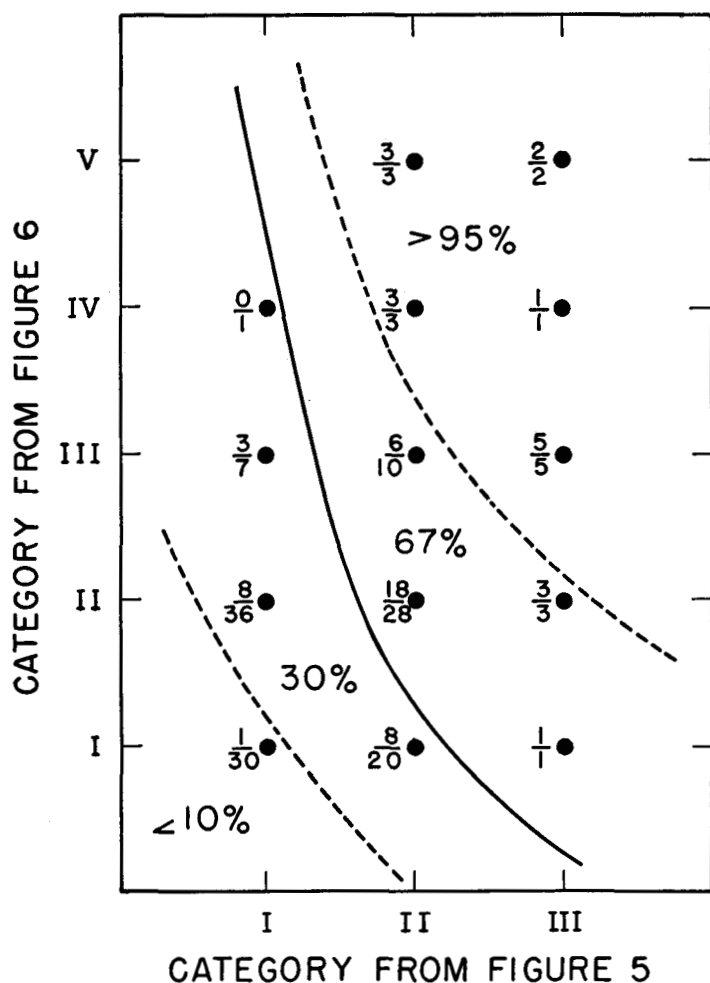


FIGURE 7.—Diagram showing combination of categories from figures 5 and 6. The fraction at each point indicates the number of precipitation cases (numerator) and the total number of cases (denominator) for the combination of categories. (For NP-A cases)

P CASES

P cases are those in which precipitation is already falling in northeast Colorado, as indicated by the 1230 GMT reports from the six synoptic stations previously listed. The variables and procedures described below apply only to these cases.

As has been indicated, if precipitation is already occurring at 1230 GMT in northeast Colorado, the question of whether or not the precipitation will continue into the forecast period depends upon whether the pressure distribution remains such that upslope conditions will persist.

The surface index described under the NP cases (fig. 3) was again found to be strongly related to subsequent precipitation. The 700-mb. index, however, did not show a worth-while relationship in the P cases.

The intensity of the low pressure that almost always exists to the southwest of the forecast area when precipitation is currently occurring in the area was considered to be important in determining if upslope flow would continue during the forecast period. To assure objectivity in measuring the intensity of the low pressure and at the same time to cover the region in which the low pressure

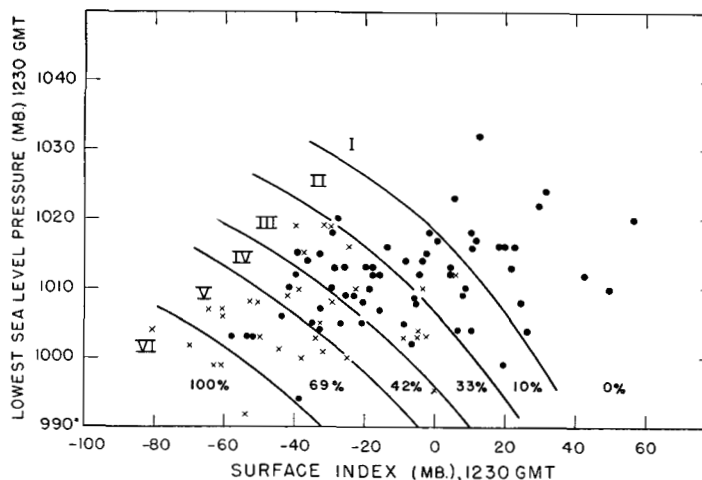


FIGURE 8.—Scatter diagram showing the joint relationship of the surface index and the lowest sea level pressure of five stations in the Southwest (Denver, Grand Junction, Salt Lake City, Grand Canyon, or Albuquerque) with subsequent precipitation in northeast Colorado. A cross indicates precipitation and a dot no precipitation. (For P cases)

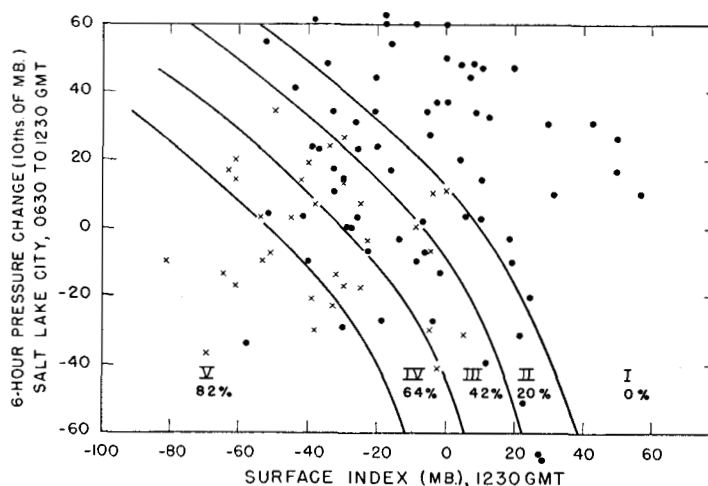


FIGURE 9.—Scatter diagram showing the joint relationship of the surface index and the 6-hour pressure change at Salt Lake City with subsequent precipitation in northeast Colorado. (For P cases)

center normally exists, the observed 1230 GMT sea level pressure was obtained at one of five stations depending upon which station had the lowest pressure. These five stations were Salt Lake City, Utah; Grand Junction and Denver, Colo.; Grand Canyon, Ariz.; and Albuquerque, N. Mex.

Another indication of whether or not upslope conditions will persist along the eastern slopes of the Rockies is the rapidity with which high pressure is moving into or building up over the Plateau region. The 6-hour pressure change (0630 GMT to 1230 GMT) at Salt Lake City was used as a measure of this condition. A fall in pressure at Salt Lake City would indicate that the easterly flow would persist, while a rapid rise in pressure would indicate movement of the low pressure to the east, the possibility of a Plateau High building up, and subsequent downslope flow east of the mountains.

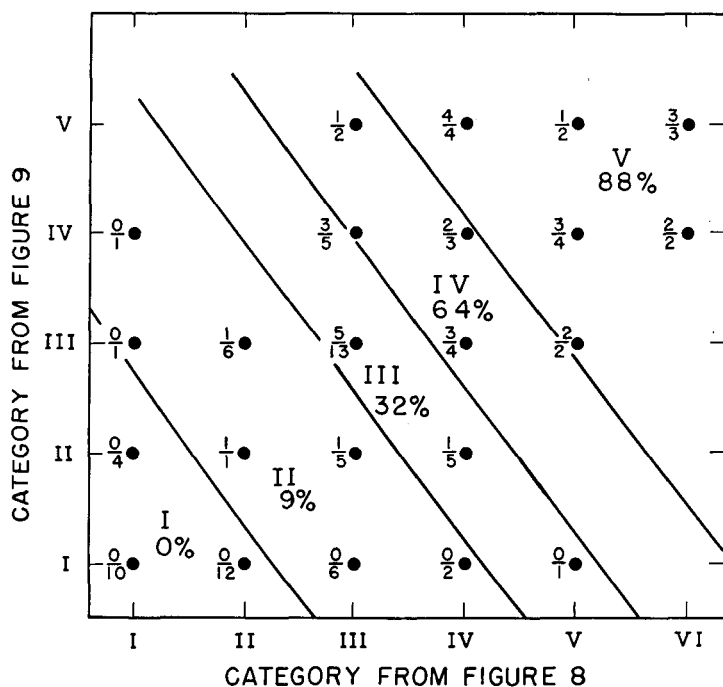


FIGURE 10.—Diagram showing combination of categories from figures 8 and 9. The fraction at each point indicates the number of precipitation cases (numerator) and the total number of cases (denominator) for the combination of categories. (For P cases)

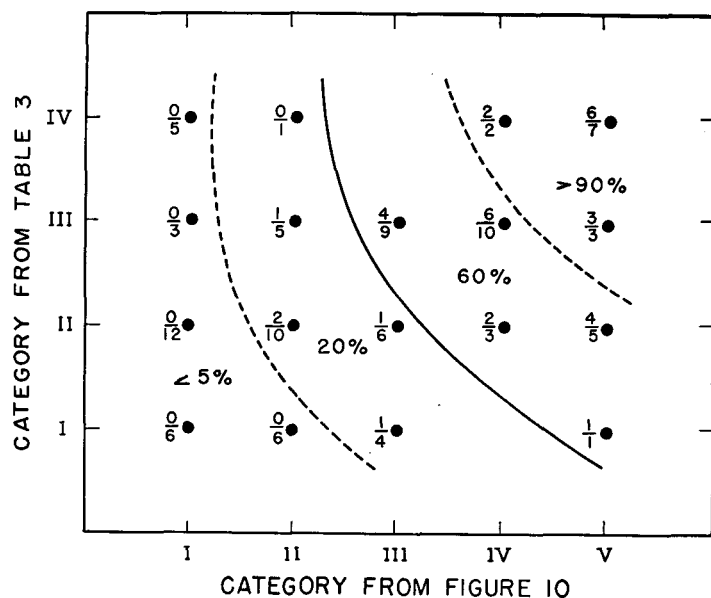


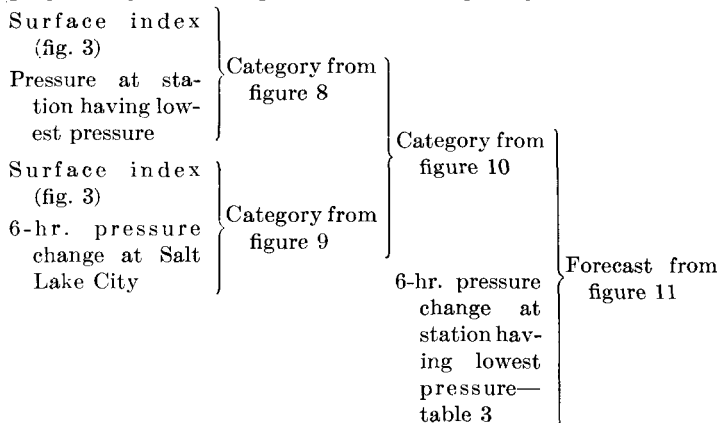
FIGURE 11.—Diagram showing combination of categories from figure 10 and table 3. The fraction at each point indicates the number of precipitation cases (numerator) and the total number of cases (denominator) for the combination of categories. (For P cases)

The change in the intensity of the low pressure to the southwest was also found to be a factor in determining whether or not upslope conditions would persist. For this purpose categories of the 6-hour pressure change (0630 GMT to 1230 GMT) at the station having the lowest pressure of the five mentioned above were utilized (table 3).

TABLE 3.—Relationship between 6-hour pressure change at station with lowest pressure (Salt Lake City, Grand Junction, Denver, Grand Canyon, or Albuquerque) and subsequent precipitation in northeast Colorado (P cases)

6-hour pressure change (tenths of mb.)	Total number of cases	Subsequent precipitation in northeast Colorado		Category
		Number of cases	Percent	
> +29	17	2	12	I
0 to +29	36	9	25	II
-1 to -29	30	14	47	III
< -29	15	8	53	IV

These four variables for the P cases were combined graphically according to the following diagram:



Thus from figure 11 a final probability of precipitation for P cases is obtained. The solid line in figure 11 is the "forecasting line", a forecast of precipitation being made above the line and a forecast of no precipitation, below the line.

## RESULTS

Of the 362 cases of original or dependent data 264 were classified as NP and 98 as P cases. Of the 264 NP cases 150 were stratified as NP-A and 114 as NP-B. The probability of precipitation in the NP-B cases is only 3 percent (see table 2), therefore the forecasts for all NP-B cases are for *no precipitation*, resulting in 97 percent accuracy for these cases. Of the NP-A cases 56 fall above the solid line in figure 7, 40 of which are precipitation cases, while 94 fall below the line of which 74 are no-precipitation cases. These figures give a percentage of 76 for correct forecasts for the NP-A cases.

Of the 98 P cases 40 fall above the solid line in figure 11, of which 28 are precipitation cases; 58 fall below the line, of which 53 are no-precipitation cases. This gives 83 percent correct forecasts for the P cases.

These results are summarized in table 4 which indicates the skill scores <sup>2</sup> and overall percent correct.

<sup>2</sup> Skill scores were computed from the formula: Skill score =  $\frac{C - E_c}{T - E_c}$

where:

C = Number of correct forecasts

T = Total number of cases

E<sub>c</sub> = Expected number of correct forecasts due to chance based on the marginal totals of the contingency table.

When the procedures were applied to the independent or test data the results shown in tables 5 and 6 were obtained.

TABLE 4.—Contingency table of results of "forecasts" made by objective procedures on original data. (January, February, and March 1944, 1946, 1947, 1948)

		Forecasts				
		Pre- cipi- tation	No pre- cipi- tation	Total		
Observed cases	P cases	Precipitation.....	28	5	33	Percent correct: 83 Skill score: .63
		No precipitation.....	12	53	65	
		Total.....	40	58	98	
	NP-A cases	Precipitation.....	40	20	60	Percent correct: 76 Skill score: .49
		No precipitation.....	16	74	90	
		Total.....	56	94	150	
	NP-B cases	Precipitation.....	0	3	3	Percent correct: 97 Skill score: .00
		No precipitation.....	0	111	111	
		Total.....	0	114	114	
	All cases	Precipitation.....	68	28	96	Percent correct: 85 Skill score: .60
		No precipitation.....	28	238	266	
		Total.....	96	266	362	

TABLE 5.—Contingency table of results of "forecasts" made by objective procedures on test data (January, February, and March 1945 and 1949)

		Forecasts				
		Pre- cipitation	No pre- cipitation	Total		
Observed cases	P cases	Precipitation	16	2	18	Percent correct: 78 Skill score: .54
		No precipitation	11	29	40	
		Total	27	31	58	
	NP-A cases	Precipitation	16	10	26	Percent correct: 72 Skill score: .42
		No precipitation	10	40	50	
		Total	26	50	76	
	NP-B cases	Precipitation	0	5	5	Percent correct: 89 Skill score: .00
		No precipitation	0	41	41	
		Total	0	46	46	
	All cases	Precipitation	32	17	49	Percent correct: 79 Skill score: .47
		No precipitation	21	110	131	
		Total	53	127	180	

TABLE 6.—Contingency table of results of "forecasts" made by objective procedures on test data (November and December 1947 and 1948)

		Forecasts				
		Pre- cipitation	No pre- cipitation	Total		
Observed cases	P cases	Precipitation	7	6	13	Percent correct: 74 Skill score: .36
		No precipitation	6	27	33	
		Total	13	33	46	
	NP-A cases	Precipitation	16	6	22	Percent correct: 84 Skill score: .58
		No precipitation	8	55	63	
		Total	24	61	85	
	NP-B cases	Precipitation	0	4	4	Percent correct: 92 Skill score: .00
		No precipitation	0	48	48	
		Total	0	52	52	
	All cases	Precipitation	23	17	39	Percent correct: 84 Skill score: .50
		No precipitation	14	130	144	
		Total	37	146	183	

To test the accuracy of the charts in expressing the probability of widespread precipitation in northeast Colorado, the percentage of precipitation cases for all test data was determined for class intervals of computed probability as shown in table 7. The first three observed percentages fall within their class intervals but are somewhat lower than the percentages in the original data. The percentage in the last interval, however, falls off radically from the greater-than-90-percent range indicated by the original data. Consideration of all the data indicates that instead of being greater than 90 percent, the true probability in this range based on the variables in this study is nearer 80 percent.

TABLE 7.—Observed percentage of precipitation occurrences in class intervals of computed probability. (All test data)

Computed probability	Total cases	Precipitation occurrences	
		Number of cases	Percent of cases
0-10.....	152	14	9
10-50.....	121	20	17
50-90.....	63	36	57
>90.....	27	18	67

Since all factors contributing to precipitation in northeast Colorado have not been evaluated, the limitations of this method should be kept in mind. Considerable skill can be obtained by the exclusive use of these techniques alone, but in certain phases it should be possible to make improvements by the subjective experience of the user. Therefore, this method should not be considered as a complete forecasting system, but as an auxiliary tool which permits the forecaster to evaluate systematically several important meteorological variables. Better results are possible if unevaluated factors are kept in mind.

## SUMMARY

For purposes of application, the following summary of the method may be useful. A precipitation day is defined as a day on which more than 33½ percent of the selected Cooperative Stations reported precipitation during the period 1730 MST one day to 1730 MST the following day. This period coincides with the forecast period. The forecast is made from the 1230 GMT (0530 MST) surface map and 12-hour pressure change chart and the 0300 GMT (2000 MST) 700-mb. chart. The steps to be taken in making a forecast by the method are:

1. Determine if the day is a P or NP case. This is based on the current precipitation (at 1230 GMT) at the following stations: Cheyenne, Sidney, North Platte, Goodland, Akron, and Denver. If precipitation is reported at any one of these stations the day is classed as a P case. If no precipitation is reported at any of the stations the day is classed as an NP case.

2. If the day is an NP case, check the Salt Lake City sea level pressure and the past six-hour precipitation in eastern Montana at the following stations: Havre, Billings, Lewistown, Miles City, Glasgow, and Sheridan. If there has been no precipitation at any one of the six stations and the Salt Lake City pressure is greater than 1016 mb., classify the case as an NP-B case, and forecast *no precipitation*. Otherwise, classify the case as NP-A and consider other variables.
3. If the day is an NP-A case, compute the surface index and 700-mb. index as illustrated in figures 3 and 4. Enter figure 5 with the values of these two indices and determine a category number.
4. From the 12-hour pressure change chart (0030 GMT to 1230 GMT) determine the position of the center of falls within the area bounded by the 95th and 125th meridians and the 30th and 55th parallels of latitude. If no definite center lies within the area, obtain the position of the greatest fall. Enter figure 6 with this position and determine a category number.
5. Enter figure 7 with the category numbers from figures 5 and 6 and forecast *precipitation* if the point determined by the two category numbers falls above the solid line and *no precipitation* if below the solid line.
6. If the day is classified as a P case under (1) above, evaluate the following variables:
  - (a) Surface index (fig. 3).
  - (b) The sea level pressure at whichever of the following stations has the lowest pressure: Salt Lake City, Grand Junction, Grand Canyon, Albuquerque, or Denver.
  - (c) The 6-hour pressure change (2330 MST to 0530 MST) at Salt Lake City.
  - (d) The 6-hour pressure change (0630 GMT to 1230 GMT) at the station in (b) above having the lowest pressure.
7. Enter figure 8 with the surface index and sea level pressure at the station with lowest pressure and determine a category number.
8. Enter figure 9 with the surface index and the 6-hour pressure change at Salt Lake City and determine a category number.
9. Enter figure 10 with the category numbers from figures 8 and 9 and determine a category number.
10. Enter table 3 with the 6-hour pressure change at the station with lowest pressure and determine a category number.
11. Enter figure 11 with the category numbers from figure 10 and table 3. Forecast *precipitation* if the point falls above the solid line and *no precipitation* if below the solid line.

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